Measurement of the magnetic properties of the Ferroxcube 8C12m material*

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Introduction

The accelerating cavities which are operated in the GSI SIS 18 synchrotron for the acceleration of heavy ions at harmonic number 4 are filled with Ferroxcube 8C12m ferrite material. The characteristics of such materials depend on a variety of parameters, notably the external bias magnetic field. This distinctive feature is used for tuning of the resonance frequency of the cavity according to the revolution frequency of the heavy ions. Evidently, for a better understanding of the tuning process, the knowledge of relevant material characteristics is inevitable. To this end, experiments were carried out at the GSI facility with the aim of determining the dependence of the complex permeability of the Ferroxcube 8C12m material both on the frequency and on the bias magnetic field strength.

Measurement setup

The basic measurement setup is as follows. Two ferrite ring cores equivalent to the ones actually installed in the SIS 18 cavity are mounted inside a copper cavity (cf. Fig. 1). The toroids can be biased via 105 crossed current windings with the help of the direct current I_{bias}. Moreover, the necessary alternating components are coupled to the device under test via one additional circuit, which consists of a centric wire and the cavity housing. This circuit is connected to a network analyzer (NWA) for the measurement of the input port voltage reflection coefficient, i.e. the S_{11}-parameter. For preparation of a defined remanence state, the bias current is driven to the maximum value for a short time.

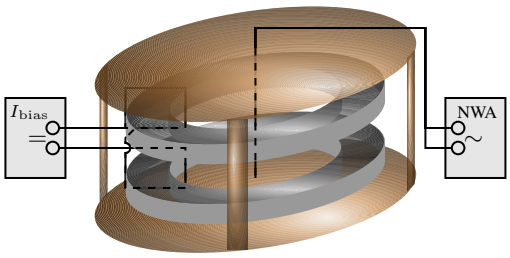

Figure 1: Schematic view of the measurement setup. Two ferrite ring cores with bias current windings are installed inside a cavity housing.

Data analysis

After the measurements, the real and imaginary part of the admittance of the device are available as a function of frequency for different bias currents. The values of the permeability are then extracted as follows. Firstly, it is assumed that the system can be described by an equivalent circuit, whose admittance is given by

$$Y = \frac{1}{R_0} + \mathrm{i}\omega C_{\mathrm{dist}} + \frac{1}{\mathrm{i}\omega L_{\mathrm{s}} + R_{\mathrm{s}}},$$

with the external resistance $R_0 = 50\,\Omega$, the distributed capacitance C_{dist} and the inductance and resistance of the toroids in series representation L_{s} and R_{s}, respectively. Whereas C_{dist} is obtained from a separate measurement, it is possible to formulate analytical expressions for L_{s} and R_{s}, which involve only geometric quantities and the complex permeability $\mu_{\mathrm{s}} = \mu'_{\mathrm{s}} - \mathrm{i}\,\mu''_{\mathrm{s}}$. Hence, by solving for the real and imaginary part of μ_{s}, one can finally evaluate the complex permeability for each frequency point. The obtained values for two different bias magnetic field strengths are shown in figure 2.

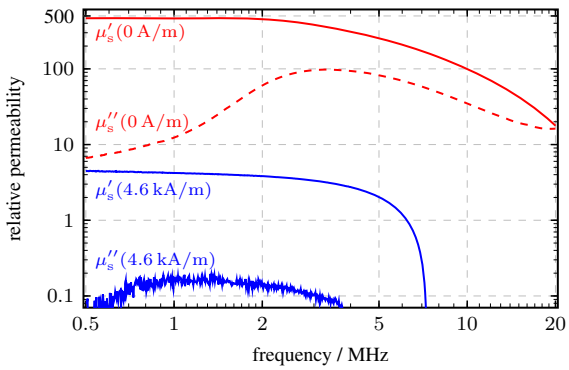

Figure 2: Real (μ'_{s}) and imaginary part (μ''_{s}) of the permeability as obtained from the data analysis for a bias magnetic field strength of $0\,\mathrm{A/m}$ and $4.6\,\mathrm{kA/m}$ (low RF-power values).

Summary and outlook

The complex permeability of the Ferroxcube 8C12m material was obtained from measurement as a function of both frequency and bias magnetic field strength. A more detailed data analysis together with a discussion of the obtained results will be published in the near future.

* Work supported by GSI
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